7.—Notes on the Geology of the Carnarvon (Northwest) Basin, Western Australia

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Because of recent oil finds, the Carnarvon Basin, otherwise known as Northwest Basin, so named by A. Gibb Maitland in 1901, occupies a position of paramount importance among the major sedimentary basins in Australia. To exploit its possibilities detailed knowledge of its stratigraphy and structure is a necessity. The first comprehensive report on the geology of the Carnarvon Basin, since Raggatt's studies in 1936, has recently been published by Condon (1954) and the following comments on and corrections to this report are offered in an endeavour to clarify parts of the stratigraphy and to point out alternative structural interpretations.

Palaeontological Zoning

On p. 71, Condon lists a fossil assemblage from the Bulgadoo shale in which *Calceolispongia barrabiddiensis* and *C. acuminata* are included, together with *Pseudoschistoceras simile*. It should be noted that these two species of *Calceolispongia* are rather widely separated stratigraphically. *C. acuminata* is restricted to the top of the Bulgadoo Shale although its occurrence is probably slightly lower than indicated in a previous diagram (Teichert, 1949, pl. 26). *C. barrabiddiensis* occurs with *Pseudoschistoceras simile* in the Barrabiddy member (Teichert, 1952) of the Bulgadoo Shale, about 2,100 feet below the top of the formations. The two species of *Calceolispongia* characterize different palaeontological zones, which are at least 1,500 feet apart stratigraphically.

The most characteristic fossil of the Quinnanie Shale (p. 75-78) is *Hyperamminoides acicula* Parr which occurs in great quantities at the type locality and in all outcrop belts of the formation in the fault blocks to the east of Wandagee Hill. Everywhere these foraminifera can be washed in huge numbers out of the shales or their residual soils. Condon does not mention the occurrence of this fossil.

The measured section of the type Wandagee Formation (p. 79-80) gives an inadequate picture of the palaeontological zonation of this formation which has been carried out in great detail. It is impossible to repeat here the details which have been given elsewhere (Teichert, 1952). On p. 80 Condon mentions 66 feet of medium-hard grey quartz greywacke etc. from which he lists *Calceolispongia elegantula* and *C. multiformis*. These two crinoid species are excellent index fossils, but they do not occur together. *C. elegantula* is abundant in and very characteristic of the lowermost 80 feet of the Wandagee Formation (from which it is not listed by Condon); *C. multiformis* is restricted to beds 165-185 feet above the base of the formation. The position of the bed from which Condon lists these two species is at 102-162 feet above the base of the formation. It has been noted before (Teichert, 1949, p. 77, pl. 15 figs. 16-21) that some basal plates of *C. multiformis* resemble *C. elegantula*, but care should be taken in distinguishing the two species. This is always possible if comprehensive collections are available.

Stratigraphy

It is difficult from Condon's paper to obtain a clear picture of the relationships of the Norton and Nalbia Greywackes and the Baker Formation. Since I am personally responsible only for the Nalbia "Greywacke," I shall restrict my remarks to that formation. As it appears that Condon has had difficulties in tracing the formation outside the type section, 0.9 mile west of Quinnanie corner, the following notes on its distribution may be helpful: at the type section, the strike of the Nalbia Sandstone is N 20° W and it can be followed in this direction for approximately 1 mile until it is cut off by north-south striking fault. The same formation outcrops again in the next fault block to the west where its bottom crosses the south fence of Coolkilya Paddock 1,540 yards from the place where the top of the formation crosses the fence further east. This is on the east flank of the "Coolkilya syncline," the axis of which strikes N 10° W with a slight northerly plunge. The Nalbia Sandstone can be followed around the greater part of this syncline whose center is filled with rocks of the Coolkilya Formation. 450 yards south of the fence, in Woollies Paddock, the Nalbia Sandstone swings around the southern nose of the syncline. The northern part of the syncline is partly covered with dune sand. South of this sand area the total traceable outcrop belt of the Nalbia Sandstone is at least 4.5 miles long. There are also some outcrops of it to the north of the sand area and south of an important cross-fault, striking N 60° E, which cuts off the Coolkilya syncline on the north. All over this area the Nalbia Sandstone retains not

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Plate 1.—Oblique aerial view of the highly faulted area south of Minilya River in the vicinity of Wandagee Hill, taken fro 15,000 feet, looking due north. (West Aust. Trimet Run 207, 81 R). The Minilya River is seen in the upper part of pictur a sand plain extends to the north of it. Drainage channel in middle of picture flows into Cundy Dam, drainage chann in foreground into Mungadan Dam.

Indicated by back circles O:
1 Wandagee Homestead,
2 Mouribandy Dam,
3 Wandagee Wool Shed.

Indicated by △: Wandagee Hill Trig. Station.
Entire lines: formational boundaries.
Dashed lines: faults.
m—Mungadan Sandstone
c—Coolkilya Sanstone
n—Nalbia Sandstone
w—Wandagee Formation
q—Quinnanie Shale
d—Cundlego Sandstone
b—Bulgadoo Shale
G—Gypsum

Note that most faults in the Permian are broadly arcuate, the convex side of the arc facing west. These are th east-dipping, normal antithetic faults. The fault in the west that separates Cretaceous from Permian rocks is a steeply west dipping normal fault.

The syncline to the north of Wandagee Hill has been referred to as "Coolkilya syncline" in this and previous publications.

The cross-section Fig. 1 runs E-W almost exactly through the middle of the photograph. Alluvial formations are not indicated.

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only its lithological characteristics, but also its palaeontological features with a rich *Schizodus-Oriocrassatella* assemblage in the lower part and abundant *Cleiothyridina* near the top.

North of the Minilya River the Nalbia Sandstone outcrops in the syncline whose axis intersects the north bank of the river 650 yards north-east of Curdamuda Well. Outcrops of the Nalbia Sandstone, here unfossiliferous, are restricted to a narrow belt on the north side of the river.

Excellent outcrops of the Nalbia Sandstone are also found further south in Woollies Paddock. The belt of Nalbia Sandstone begins a little over 600 yards N 20° E of Wandagee Wool Shed where the beds strike 85°, dipping 30° S. The formation can be followed in a straight line along the strike for 1600 yards to a position just inside Dry Paddock where it is cut off by the major fault which runs along the west side of Wandagee Hill. In this outcrop belt both the lower pelecypod zone, and the upper *Cleiothyridina* zone are well developed.

Further south the characteristic pelecypod assemblage disappears but the *Cleiothyridina* zone is well recognizable around the nose of a little north-plunging anticline 1,600 yards south of Wandagee Wool Shed on the road to Mungadan Dam. This is close to the Cretaceous boundary fault and from here the Nalbia Sandstone can be followed first in a south-easterly direction, then swinging around the southern nose of the north-plunging syncline which lies west of Wandagee Hill.

East of Wandagee Hill, the Nalbia Sandstone becomes unfossiliferous, but retains its characteristic lithology. It occurs in two fault blocks which are separated by a curved east-dipping normal fault. The western-most of these blocks includes Wandagee Hill itself. The Nalbia Sandstone emerges from underneath a Pleistocene talus stream at a place 1,650 yards N 30° E of Wandagee Hill Trig. Station. It swings around Wandagee Hill in a wide, almost circular arc, and it is cut off by a fault 3,250 yards S 20° E of the same Trig. Station. About half way down the outcrop belt approaches to within 40 or 50 yards of the eastern boundary of Mungadan Paddock, but does not cross into Nalbia Paddock. The outcrop belt in Nalbia Paddock belongs to another fault block. On a bearing due east of Wandagee Hill Trig. Station, this belt lies at a distance of 2,900 yards from the latter and strikes about N 20° W, dipping west. To the north, the strike swings further west; to the south, it swings almost into a north-south direction. Total length of the outcrop belt is nearly 2 miles. On both ends, it terminates against the same curved fault which separates this block from the one to the west. On the whole, I should say that it would be difficult, if not impossible, in the closely faulted area east and north of Wandagee Hill, to map the Nalbia Sandstone from aerial photographs. Condon seems to have confused the Nalbia Sandstone with his "Norton Greywacke" and "Baker Formation." The type localities of these two formations are situated 30 to 40 miles from that of the Nalbia Sandstone and there is, as far as I know, no continuity of outcrops over the intervening area. Correlation between the northern Kennedy Range and the Wandagee area can only be established by means of close palaeontological control which has received little attention in Condon's report. Since Condon refers to a small outcrop area of the Norton Greywacke in the syncline north of the Minilya River " 9 miles west of Wandagee Homestead" (=650 yards north-east of Curdamuda Well, see above), there seems to be no question that in the Wandagee area he applied that name to the unfossiliferous or less fossiliferous facies of the Nalbia Sandstone.

This conclusion is also supported by his references to the heavy mineral work by Higgins and Carroll (1940). According to Condon, Higgins and Carroll's samples 1, 3 and 5 come from the Norton Greywacke. I collected these samples myself and to the best of my recollection, sample 3 comes from the Nalbia Sandstone, samples 1 and 5 come from somewhat higher beds, namely from the "*Fenestella* nodule beds" of the Coolkilya Formation. It should be remembered that Higgins and Carroll showed that there is no striking variation in heavy mineral amounts in the sequence below the "Wandagee Hill beds" (Mungadan Sandstone of present nomenclature) and that heavy minerals, therefore, offer little support in the correlation of these lower beds.

While it thus seems certain that "Norton Greywacke" is a synonym of the Nalbia Sandstone, perhaps including the lowest part of the Coolkilya Formation, it is more difficult to be sure which beds in the Wandagee area Condon correlates with the Baker Formation of the Kennedy Range. He says it overlies the "Norton Greywacke" which I have shown to be essentially identical with the Nalbia Sandstone. It would then seem that the Baker Formation corresponds to the lowest part of my Coolkilya Formation. However, this is characterized everywhere in the Wandagee area by light-grey weathering calcareous sandstone nodules with many specimens of *Fenestella*. Of these, there is no mention in Condon's report. In the Coolkilya syncline *Helicoprion*, together with *Propinacoceras*, *Paragastrioceras* and *Pseudogastrioceras*, was found just above the *Fenestella* nodule beds, but Condon (p. 87) refers the beds with these fossils to the Nalbia "Greywacke." Part of Condon's Nalbia "Greywacke" is thus older, part younger than the "Baker Formation." Apparently, there is something wrong with this correlation and further work is needed. If possible, this should be carried out mainly on the ground. If no continuity of outcrops can be established between the Kennedy Range and the Wandagee area, it would be better to apply a separate nomenclature to the two areas, unless correlations can be made beyond reasonable doubt.

On p. 97, Condon states that "the boundary between the Coolkilya Sandstone and the Mungadan Sandstone defined by Teichert (1952), is not a main lithological boundary" and he, therefore, proposes to revise the definition of these two formations. However, after reading his description of the upper part of the Coolkilya Sandstone in its type locality east of Wandagee Hill, I have little doubt that Condon's and my upper boundaries of this formation are the same. The top unit in Condon's section is "2 feet of hard red-brown ferruginous coarse-grained quartz

greywacke, with interior and exterior moulds of spiriferids, pectenids and *Oriocrassatella*." There are actually two such red-brown horizons (which I had called "dark purple") only a few feet apart. The two can be followed all around the east side of Wandagee Hill and I chose them as markers for the top of the Coolkilya Sandstone (Teichert, 1952). In earlier papers (Teichert, 1949) this horizon had been called the top of the "*Linoproductus* beds of the Wandagee Series." There is thus no discrepancy between Condon's and my interpretation of the boundary between the Coolkilya "Greywacke" and the Mungadan Sandstone. Condon, however, omits to mention that the uppermost "red-brown" horizon with *Oriocrassatella* also marks the last occurrence of *Calceolispongia robusta*, an important index fossil of the Coolkilya Formation. Important members of the fauna of the latter are *Agathiceras*, *Pseudogastrioceras* and *Dictyoclostus*, all of which mark horizons in the upper part of the formation. On p. 94, Condon lists *Calceolispongia cf. rotundata* from the Mungadan Sandstone in a section in the Kennedy Range. That species, however, is restricted to the lower 165 feet of the Wandagee Formation, and, if correctly identified, suggests correlation of the beds in question with the Wandagee rather than the Coolkilya Formation.

Peculiarly, Condon has entirely omitted mention of the calcareous eolianites (or "coastal limestones") of Pleistocene, most probably Würm, age. These rocks are widespread along the coast north of Warroora as far as the vicinity of Cardabia Homestead. They are quite similar to the same formations well known elsewhere from Western Australia (see various joint and individual papers by Fairbridge and by Teichert) and their study is important for the interpretation of the late Quaternary history of the area. At Point Anderson, 6 miles south of Maud Landing, there are clearly two generations of eolianite, each topped by a travertinized layer which here takes the place of the rendzina soils developed between successive dune generations in more southerly latitudes (Fairbridge and Teichert, 1953). The fact that the earliest visible eolianite is now partly submerged, presents evidence for a comparatively recent rise in sea-level. From analogy with conditions in the south this rise should be post-Würm.

Structure

Condon's discussion of the fault mechanics of the Carnarvon basin (pp. 135-138) is interesting, but his interpretation is not supported by the facts, at least not in those parts of the basin known to me. I shall restrict my discussion to Condon's section C-D on Plate 2, part of which is here reproduced as fig. 1A. The position of this section virtually coincides with that of one published by Clarke, Prider and Teichert (1944, p. 94) which was based on the present writer's at that time unpublished data, and to which Condon does not refer. In comparing such sections, and the interpretation they represent, it must be borne in mind that the faults themselves are rarely exposed. Their presence can be discovered by mapping, but their dips can, in most cases, only be inferred from general considerations. Condon believes that almost all faults in the Carnarvon basin are reversed or thrust faults and since (p. 138) he bases important economic conclusions on this interpretation, the matter is of more than theoretical interest. Condon himself records "a marked absence within the sediments of evidence of compression such as compressional joint systems, cleavage and drag-folds," but believes that this can be explained by assuming that "the stress which caused the faulting was carried mainly by the pre-Cambrian basement and that the faults in the sediments result from the faulting of the basement." Nevertheless, if there is upthrust in the basement, at least some of the usual manifestations of thrust-faulting should be discoverable in the sedimentary mantle here and there.

However, to say that evidence of compression is lacking is definitely an understatement, because wherever faulting is observed along the section here discussed, the evidence for tensional stresses is overwhelming. These are of three kinds: (1) abundance of calcitic veins as fillings of tension gashes everywhere near faults; (2) occurrence of wide tension rifts filled with secondary gypsum; and (3) the scattering of small blocks of sediments in random orientations along fault zones. The latter show no signs of crushing by compression such as one might expect along thrust-faults, but are simply blocks that have slumped into cracks opened up by faulting. Gypsum zones along faults are well developed and most easily observed in the following places: In Nalbia Paddock of Wandagee Station there is a gypsum belt whose southern end lies 2,250 yards almost due east of the Trig. Station on Wandagee Hill. From here it runs almost due north for about 1,500 yards, then swinging gradually into a more north-easterly direction. Its total length is over 1.5 miles and its greatest width at least 100 yards. The throw of this fault at the southern end of the gypsum belt is about 1,000 feet, decreasing towards the north. In 1940 and 1941, a large, widely visible eucalypt tree ("white gum" or "river gum") grew in the middle of this belt. If the tree is still there, the place should be easy to find.

Another narrower and longer gypsum belt is found in Dry and Coolkilya Paddocks on Wandagee Station. It crosses the fence between the two paddocks at 2,200 yards west of Quinnanie Corner, where it strikes almost due north and is about 50 feet wide. Southward it can be followed for about 0.5 mile until it disappears under alluvial cover. To the north, it extends at least 1.5 miles and marks a somewhat oblique fault along which first Coolkilya Formation, then Nalbia Sandstone, are cut off. To the west of the fault are flats underlain by Quinnanie Shale characterized by abundant *Hyperamminoides* (see above). The throw of the fault where it crosses the fence is approximately 1,200 feet.

These are two outstanding examples, but gypsum is found along fault zones elsewhere in the area.

Good surface evidence for east-dipping normal faults is found along the section line (Fig. 1) about halfway between Wandagee Hill and Williambury where, at Trig. Station K55 and to the east thereof, it intersects three fault

PLATE 2.—Oblique aerial view along east coast of Salt Lake (or "Salt Marsh"), taken from 15,000 feet, looking due south from point above upper part of lake. (West Australian Trimet Run 205, 66 R, 10). From lower left through centre of picture trends Chirrida anticline with 12-ft. terrace along its entire western flank. Note weakly incised consequent drainage on both flanks of anticline. The small, early Recent deltas on the terrace are not recognizable from this altitude, but the newer Recent deltas in front of the terrace are clearly visible.

Headland in upper right of picture is Sandy Bluff. The first river to the left (east) of it is the Minilya River; the next river is Barrabiddy Creek.

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blocks consisting of Callytharra Limestone and Wooramel Sandstone. These fault blocks form gently inclined west-sloping cuestas in which the hard Wooramel Sandstone has protected the softer Callytharra limestones and shales which form steep east-facing cliffs. At least near K 55 itself, and at the escarpment in the next block to the east, the faults (which are not exposed) must be situated quite close to the base of the escarpments. I have visited both localities several times and examined the rocks in detail. I am sure that there is no sign of upthrusting along these escarpments and that, as indeed one might expect, the cuestas owe their existence to a westward tilt of the fault blocks, along normal faults on both sides.

Fig. 1B shows the structures which one would expeet to find along the selected section if the hypothesis of thrust-faulting were correct. Although I am familiar with the detailed geology around all the faults shown in this section, I have never seen any field evidence suggesting structures of this kind. On the contrary, all the evidence, circumstantial and observational, supports the assumption of normal faults.

Fig. 1C shows how the structures can be interpreted as the result of normal faulting. There are some normal west dipping faults, the only major one probably in the Precambrian to the east. The dominating pattern is that of a set of antithetic, east-dipping adjustment faults (Teichert, 1948, 1952).

Antithetic faults were named and discussed by Cloos (1928), although they were well known before. They are due to rotational movements of fault blocks during which each block carries out a rotating movement around its centre of gravity. Such movements result from tension fracturing of sedimentary table lands, especially in wide flexure zones, if part of the sedimentary table is elevated. In such a situation, the stresses normally lead to formation of a small number of major faults which dip in the direction of the regional structural dip and are therefore called *homothetic* by Cloos, combined with a system of numerous faults which dip against the regional dip (hence, *antithetic*) and which assist in the release of tensional stresses. Such fault systems have been reproduced experimentally (Cloos, 1932) and they occur widely in nature (Cloos, 1936, pp. 226-269), particularly along continental margins (Cloos, 1939, p. 504). Generally the plane of the antithetic fault lies approximately at right angles to the plane of the beds of the respective fault block, or it may be slightly more gently inclined. In the faulted country between Wandagee Hill and Williambury, the prevailing dips of strata are between 20° and 25° west. The faults, separating the fault blocks, may therefore be expected to dip 65° to 70° east, but their dips may be as low as 50°. The entire fault pattern is due to uplift of the Precambrian basement in the east.

There is no good evidence to suggest where exactly the coast was situated during Devonian, Carboniferous and Permian time, except that it must have been well to the east of the present easternmost distribution of Palaeozoic rocks, that is, well inside of what is now the Western Australian Precambrian shield. In Palaeozoic times, the present shield margin formed part of the subsiding basement on which thick sedimentary series accumulated. In post-Palaeozoic times, the marginal sedimentation area was uplifted and its basement became part of the shield.

The overall regional rise of the Precambrian basement from the coast to the present edge of the Western Australian shield is of the order of 200 to 250 feet per mile. In other words, there is an overall seaward dip of the surface of the Precambrian of approximately 2°. The tensional stresses created by the uplift of the shield were released in the manner here suggested, by a few widely spaced west-dipping normal faults, and a system of numerous more closely spaced east-dipping antithetic faults.

The age of the main uplift which caused this structure pattern is pre-Cretaceous, because the Cretaceous transgresses over a faulted Palaeozoic basement. In places there has been some post-Cretaceous faulting, probably caused by continued uplift of the shield. The post-Cretaceous fault west of Wandagee Hill is a normal west-dipping fault which is possibly posthumous to a pre-Cretaceous antithetic east-dipping one. The possibility should be kept in mind that the pre-Cretaceous tensional fault pattern which is visible on the surface east of Wandagee Hill, continues westward below the infra-Cretaceous unconformity. This possibility has not been indicated on the sections Fig. 1A-C.

Discussing the oil possibilities of the Carnarvon Basin, Condon suggests that the thrust faults which he believes to exist in the basin "may provide adequate structural closure in some cases" (p. 154). Our interpretation affords no basis for such optimism. Antithetic tension faults will facilitate the escape of hydrocarbons. The search for oil in the Carnarvon basin must, therefore, be restricted to anticlinal structures and to structural and stratigraphic traps below the Cretaceous-Permian unconformity. It will be of the utmost practical importance to determine the exact age of the dislocations of the Palaeozoic rocks. The longer the interval between this tectonic episode and the Lower Cretaceous transgression, the greater the chances for Palaeozoic oil having escaped before it could be trapped.

Age of the Anticlinal Structures

In the western part of the basin occur a number of remarkable anticlines and domal structures all of which have been named and briefly described by Condon. He attributes their origin to upthrusts in the basement and for some of the major anticlines, such as Cape Range and Giralia, he states evidence for a two-stage uplift, both of which occurred after the deposition of the Miocene Trealla Limestone, and before the Pleistocene. Essentially then the formation of these, and by implication of all other anticlines is held to be epi-Miocene to Pliocene in age. While I find myself in basic agreement with these conclusions I believe that it is possible to demonstrate that the uplift of some anticlines took place later, or at least continued into post-Pliocene times.

Condon describes the occurrence of marine shell deposits in the vicinity of the Salt Lake to heights of 20-25 feet above present lake bottom. He does not, however, mention the presence of the remarkable terrace which is cut into

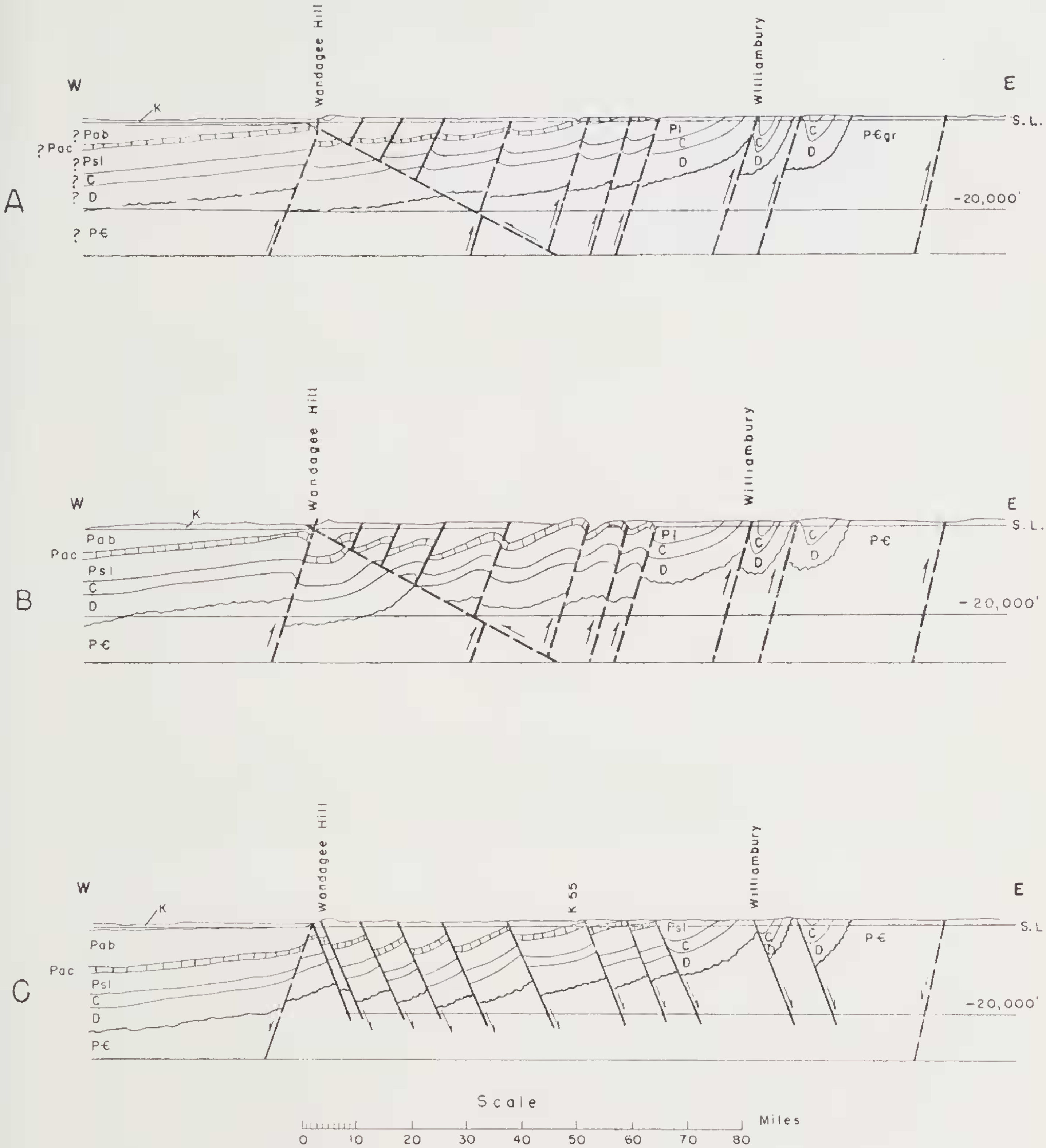

FIG. 1.—A, part of section C-D in Condon, 1954, Pl. 2. B, same section showing fictitious structures which would be in accordance with the interpretation of thrust-faulting, but which are not found in nature. C, same section showing interpretation of structures as an antithetic fault pattern. D Devonian, C Carboniferous, Psl Permian Lyons Group, Pac Permian Callytharra Limestone, Pab Permian Byro Group, K Cretaceous. Vertical scale approximately $2\frac{1}{2}$ times horizontal scale.

the west flanks of the anticlines on the east side of this generally dry lake. This terrace may be studied especially well along the entire west side of the Chirrida anticline (see Plate 2), where it lies at 11-12 feet above lake bottom level and is about 100 yards wide. It consists of loose deposits, partly shell layers, and partly sand. It is now incised by the many consequent streamlets which run off the west flank of the anticline. These little streams have cut narrow small canyons into the limestone roof of the anticline and at the mouth of each canyon a small deltaic fan can be seen to rest on the terrace. These are the deltas which were made by the consequent streamlets at the time when the sea covered the terrace. They consist of limestone rubble mixed with shells. After sea-level subsided the streamlets cut through the deltas and into the underlying terrace.

At the north end of the Salt Lake, around the mouth of the Lyndon River, there is a river terrace, 12 feet above the river flat, which consists of red, brown, and partly gypseous sand. This terrace is particularly well developed east of the Lyndon River where it is up to half a mile wide. It is in the same position, hence most probably of the same age as the terrace along the west side of Chirrida anticline.

What is the age of the terrace and its superimposed deltas? The height of 11-12 feet above lake bottom as well as the remarkable persistency of the feature immediately suggest correlation with the 10-ft. bench which has been so widely recognized in the southwestern part of Western Australia (see Teichert, 1947, 1950; Fairbridge, 1950; Fairbridge and Teichert, 1953; and other papers by the same authors) and the age of which is regarded as early Recent. This dating is supported by the youthful appearance of the terrace and its deltas. The small size of the latter would suggest that they represent a comparatively short span of time.

The position of the terrace poses some interesting problems. Condon stated (p. 125) that the present lake bottom is very close to ordinary high tide level, but more recent surveys by Ray Geophysics (Aust.) Pty. (kindly supplied by W.A. Petroleum Pty. Ltd. through courtesy of Professor R. T. Prider) have shown that along the Chirrida anticline the level of the lake bottom lies approximately 2 feet below mean sea-level. The tides along the coast near Carnarvon are somewhat variable, but spring range is about 4 feet (Hodgkin, 1957). The lake bottom along its eastern coast is therefore now situated at about low water springs. The surface of the terrace along the west side of Chirrida anticline must have been formed somewhere between low water and mean sea-level and it is thus apparent that little if any movement of this anticline has occurred since the mid-Recent drop of sea-level, that is during the last 3,000 or 4,000 years. Conditions along other anticlines might well be different. The study of features attributable to Late Quaternary sea-level movements, particularly the 10-ft. bench, may well be helpful in the analysis of young movements in this coastal belt. Where its present level deviates appreciably from 10 ft. above Low Water it could be deduced with great confidence that very young movements have taken place. In the case of Chirrida anticline the small amount of erosion which took place prior to and during the formation of the 12-ft. terrace seems to indicate a very young age of this structural feature which, I think, must have come into existence during the Pleistocene. There has apparently been no measurable movement since early Recent time.

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